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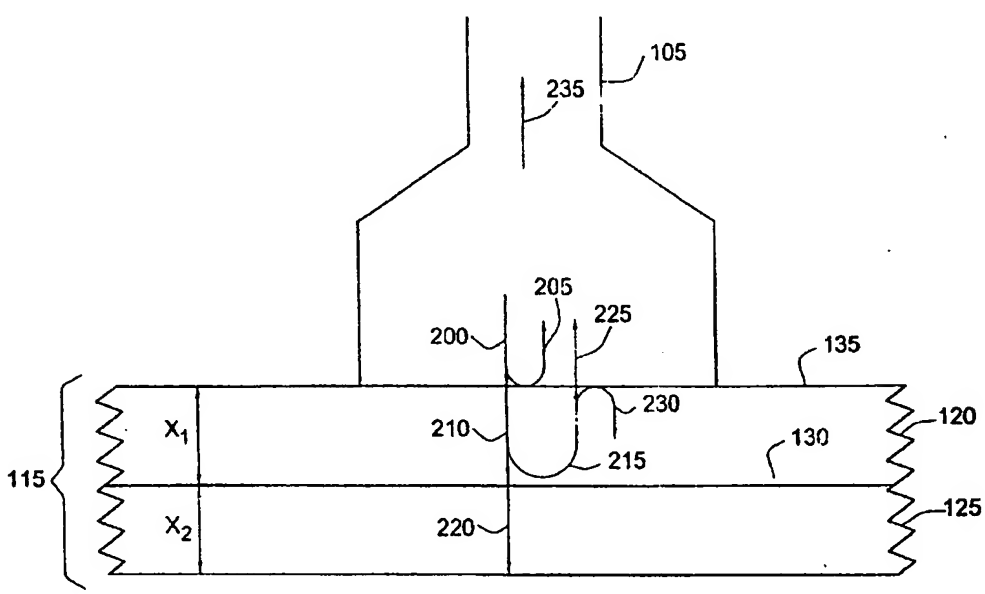
(54) Title: METHOD AND APPARATUS FOR MEASURING THICKNESS OF A LAYER IN A MULTI-LAYERED OBJECT



(57) Abstract: A method and device for determining a thickness of a layer in an object. For each of a plurality of frequencies, a continuous vibrational wave is generated at a surface of the layer and an energy of a steady state echo wave produced in the object in response to the generated vibrational wave is measured. The thickness of the layer is then calculated based upon the measured energies of the steady state echoes.

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METHOD AND APPARATUS FOR MEASURING THICKNESS OF A LAYER IN A MULTI-LAYERED OBJECT

FIELD OF THE INVENTION

The present invention relates to methods for measuring the thickness of a layer in a multi-layered object.

BACKGROUND OF THE INVENTION

There are several prior art devices for measuring the thickness of a layer in multi-layer materials.

U.S. Patents Nos. 5,974,886 and 5,197,019 disclose a method in which a short pulse vibration generated by a transducer is directed to the material. Each interface between adjacent layers generates an echo that arrives at a detector transducer at different times. The thickness of a layer is calculated as the time difference between the two echoes formed at the two surfaces of the layer multiplied by the sound velocity in the layer. However, for thin layers the time between the echoes is very small, and any error in the time measurement leads to a corresponding error in the thickness. In addition, a crystal transducer usually has several lobes, (a main lobe and side lobes) and the pulse echo of the side lobes will be superimposed on the main pulse echoes and will thus add noise to the measurement.

Another method known in the art involves submerging the material in a coupler liquid and obtaining the frequency spectrum of the material, for example, as described in U.S. Patent No. 5,351,544. This however cannot be used for *in vivo* measurement since it is impractical to introduce a coupler liquid into the body. U.S. Patent No. 5,806,520 discloses a method for determining the thickness of bone, but

this method is not accurate for hidden or hard to access tissues, or layers of small thickness.

SUMMARY OF THE INVENTION

The present invention provides an apparatus and method for measuring the thickness of hidden or hard to access layers in a multi-layer structure.

In accordance with the invention, an input vibrational wave is transmitted to the surface of the structure by means of a probe. The steady state echo of the input wave is the superimposition of a series of echoes formed at the front and back surfaces of the layer. The steady state echo is transmitted from the structure to a detector through the probe that determines the energy of the steady state echo and stores it in a memory. The frequency of the generated wave is varied, and the energy of the steady state echo at each frequency is determined and stored in the memory. As described in detail below, the thickness of the layer is then calculated from frequencies at which the intensity of the steady state echo is minimal. The invention may be used to determine the thickness of a layer in an organism. For example, the invention may be used to determine the thickness of a bone.

The invention allows non-invasive measurement of a layer thickness and may therefore be used in medical imaging procedures. The invention may be used to measure the thickness of hidden or difficult to access structures, such as bone or arteriosclerosis in an artery.

Thus, in its first aspect, the invention provides a method for determining a thickness x_1 of a layer in an object, the method comprising the steps of:

(a) for each of a plurality of frequencies $f_1,\ldots.f_k$

  (aa) generating a continuous vibrational wave at a surface of the layer;

  (ab) measuring an energy of a steady state echo wave produced in the object in response to the generated vibrational wave;

(b) calculating the thickness of the layer based upon the measured energies of the steady state echo waves.

In its second aspect, the invention provides a method a method for detecting the thickness of a bone, in an organism the method comprising the steps of:

(a) for each of a plurality of frequencies $f_1, \ldots f_k$

(aa) generating a continuous vibrational wave at a surface of the bone;

(ab) measuring an energy of a steady state echo wave produced in the organism in response to the generated vibrational wave;

(b) calculating the thickness of the bone based upon the measured energies of the steady state echo waves.

In its third aspect, the invention provides a device for determining a thickness of a layer in an object, the device comprising:

(a) a transducer configured to generate a plurality of input vibrational wave pulses;

(b) a receiver configured to receive a steady-state echo wave produced by an input vibrational wave pulse;

(c) a probe configured to transmit a vibrational wave from the transducer to a surface of the bone and to transmit steady-state echo wave from the surface to the receiver;

(d) a processor configured to

(da) determine a frequency of each of the plurality of input vibrational waves;

(db) store in a memory an energy of each of a plurality of steady-state echo waves; and

(dc) calculate the thickness based upon the stored energies of the steady-state echo waves; and

(e) a display configured to display the thickness.

In its fourth aspect, the invention provides a device for determining a thickness of a bone in an organism, the device comprising:

(a) a transducer configured to generate a plurality of input vibrational wave pulses;

(b) a receiver configured to receive a steady-state echo wave produced by an input vibrational wave pulse;

(c) a probe configured to transmit a vibrational wave from the transducer to a surface of the bone and to transmit steady-state echo wave from the surface to the receiver;

(d) a processor configured to

(da) determine a frequency of each of the plurality of input vibrational waves;

(db) store in a memory an energy of each of a plurality of steady-state echo waves; and

(dc) calculate the thickness based upon the stored energies of the steady-state echo waves; and

(e) a display configured to display the thickness.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1 is an apparatus for determining the thickness of a layer in accordance with one embodiment of the invention;

Fig. 2 shows the formation of a steady state echo from a layer in a multi-layer structure.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Fig. 1 shows an embodiment of the invention in which an ultrasound transducer **100** is configured to generate a vibrational wave pulses of variable frequencies in a long flexible probe **105**. The probe **105** is preferably made from a material having a high acoustic impedance (Z_{in}) such as metal. The probe **105** may also have a coating having a low acoustic coefficient (not shown). Distal end **110** of the probe **105** is configured to be applied onto a surface **135** of a multi-layer

structure **115**. The distal end **110** of the probe **105** is widened in order to increase the area of the contact between the distal end **110** of the probe **105**.

The structure **115** consists of two or more layers, of which two, **120** and **125**, are shown in Fig. 1. The layers **120** and **125** are in contact with each other at an interface **130**. The layers **120** and **125** have unknown thicknesses X_1 and X_2, respectively, as indicated by arrows **140** and **145**. The speed of sound in each of the layers **120** and **125**, C_1 and C_2, respectively, are known and the acoustic impedance of each of the layers **120** and **125**, Z_1 and Z_2, respectively are known to satisfy the relation $Z_{in} > Z_1 > Z_2$.

A processor **150** causes the transducer **100** to generate a series of vibrational probe waves of increasing frequency. At each frequency the ultrasound transducer **100** generates an input vibrational wave in probe **105**. The frequency of the wave is determined by a processor **155**. The probe **105** transmits the wave to the surface **135**. Fig. 2 shows an enlargement of the distal end **110** of the probe **105**. An input wave **200** of a particular frequency arrives at the surface **135**. At surface **135** some of the energy of the wave **200** is reflected from the surface **135** back into the probe **105**, to form a first echo wave **205**. The part of wave **200** transmitted into the layer **120**, wave **210**, continues through layer **120** until it reaches the interface **130**. At the interface **130** some of the wave energy is reflected back from the interface **130** (wave **215**), while some of the wave energy is transmitted into layer **125** (wave **220**). The reflected wave **215** from the interface **130** travels back to surface **135** where part of the energy of the wave **215** is transmitted back into the probe **105** to form a second echo wave **225**, and part of the energy is reflected back to the interface **130** (wave **230**).

The wave **230** has the same fate as the wave **210**, thus generating a third echo wave (not shown). Ultimately, a decaying sequence of echo waves is generated, the first and second of which are the waves **205** and **225**. The steady-state echo wave **235** is the superimposition of all of the echo waves in the sequence. The steady-state echo wave is transmitted back along the probe **105** to a

receiver **150** shown in Fig. 1.The receiver **150** produces a signal **165** indicative of the energy of the steady-state echo that is input to the processor **155** which stores the energy in a memory **170.** The processor **155** causes the transducer to generate a series of vibrational wave pulses of increasing frequency, the energy of the steady-state echo wave is stored in the memory **170.** The frequency range of the frequency increment between consecutive frequencies can be input by a user by means of a keyboard **160.**

It is known that the steady- state power transmission coefficient, α_t, from the probe **105** through the layer x_1 and into the layer x_2 depends upon the frequency f of the input wave according to the equation:

$$\alpha_t = \frac{4Z_2Z_{in}}{(Z_2+Z_{in})^2\cos^2\frac{2\pi f x_1}{c}+(Z_1+\frac{Z_2Z_{in}}{Z_1})^2\sin^2\frac{2\pi f x_1}{c}} \qquad (1)$$

(see for example Kinsler, L.E. and Frey, A.R. Fundamentals of Acoustics, John Wiley & and Sons, 1950, p. 138, Equation 6.36)

In the case that $Z_1+\frac{Z_2Z_{in}}{Z_1}\rangle Z_z+Z_{in}$

α_t has maxima occurring at frequencies f_n at which

$$\frac{2\pi f_n}{c}x_1=(2n-1)\frac{\pi}{2} \quad \text{for} \quad n=0,\pm1,\pm2,... \qquad (2)$$

from which it follows that

$$f_n=\frac{(2n-1)c}{4x_1} \qquad (3)$$

and

$$x_1 = \frac{(2n-1)c}{4f_n} \tag{4}$$

In this case, the thickness X_1 of the layer **120** is calculated by the processor **155** as follows. The processor **155** searches for a predetermined number of consecutive frequencies $f_n, f_{n+1} \ldots f_{n+k}$ at which the energy of the steady-state echo has consecutive local minima corresponding to frequencies where α_t has a local maximum.

The processor then calculates the ratio of the consecutive pairs of minimal frequencies $\frac{f_n}{f_{n+1}}, \frac{f_{n+1}}{f_{n+2}}, \ldots \frac{f_{n+k-1}}{f_{n+k}}$ and then finds n by solving the over-determined system of equations:

$$\frac{f_n}{f_{n+1}} = \frac{2n-1}{2(n+1)-1}$$

$$\frac{f_{n+1}}{f_{n+2}} = \frac{2(n+1)-1}{2(n+2)-1}$$

$$\vdots$$

$$\frac{f_{n+k}}{f_{n+k+1}} = \frac{2(n+k)-1}{2(n+k+1)-1}$$

The processor then calculates X_1 from equation 4. The results of the calculation are displayed on a display **175**.

In the case that $Z_z + Z_{in} \rangle Z_1 + \frac{Z_2 Z_{in}}{Z_1}$

α_t has maxima occurring at frequencies f_n at which

$$\frac{2\pi f_n}{c}x_1 = n\pi \quad \text{for} \quad n = 0, \pm 1, \pm 2, \ldots \tag{2'}$$

from which it follows that

$$f_n = \frac{nc}{2x_1} \tag{3'}$$

and

$$x_1 = \frac{nc}{2f_n} \tag{4'}$$

In this case, the thickness X_1 of the layer **120** is calculated by the processor **155** as follows. The processor **155** searches for a predetermined number of consecutive frequencies f_n, f_{n+1} … f_{n+k} at which the energy of the steady-state echo has consecutive local minima corresponding to frequencies where α_t has a local maximum.

The processor then calculates the ratio of the consecutive pairs of minimal frequencies $\frac{f_n}{f_{n+1}}, \frac{f_{n+1}}{f_{n+2}}, \ldots \frac{f_{n+k-1}}{f_{n+k}}$ and then finds n by solving the over-determined system of equations:

$$\frac{f_n}{f_{n+1}} = \frac{n}{n+1}$$

$$\frac{f_{n+1}}{f_{n+2}} = \frac{n+1}{n+2}$$

$$\vdots$$

.

.

$$\frac{f_{n+k}}{f_{n+k+1}} = \frac{n+k}{n+k+1}$$

The processor then calculates X_1 from equation 4'. The results of the calculation are displayed on a display 175.

EXAMPLE

An initial frequency of the input wave 200 of f_0=0.285 MHz may be used, and the frequency varied with a frequency increment of 0.056 MHz. If it is found that three consecutive minima of the steady-state echo wave occur at frequencies of 1 f_n = 0.31 MHz, f_{n+1} = 0.366 MHz, f_{n+2} = 0.421 MHz, then the calculated ratios are:

$$\frac{f_{n+1}}{f_n} = \frac{0.366}{0.31} = 1.1806$$

$$\frac{f_{n+2}}{f_{n+1}} = \frac{0.421}{0.366} = 1.1502$$

From these ratios the best fit is n_1 = 6. Using Equation (2), (with c_1 = $3.36X10^3$ m/sec.) the thickness X_1 is calculated to be 2.98 mm.

If it is found that three consecutive minima of the steady-state echo wave occur at frequencies of f_n = 4.69412 MHz,, f_{n+2} = 5.1882 MHz and f_{n+2} = 5.682 MHz.

Then the calculated ratios are

$$\left(\frac{(2(N1+1)-1)}{(2(N1-1)}\right) = 1.1052, \text{ and } \frac{f_{n+1}}{f_n} = \frac{5.1882}{4.69412} = 1.1052$$

$$\left(\frac{(2(N1+2-1)}{(2(N1+1)-1)}\right) = 1.0952, \text{ and } \frac{f_{n+2}}{f_{n+1}} = \frac{5.682}{5.1882} = 1.0952.$$

The value of n_1 that best fits is $n_1 = 10$, and X_1 is calculated to be 0.34 mm.

CLAIMS:

1. A method for determining a thickness x_1 of a layer in an object, the method comprising the steps of:

   (a) for each of a plurality of frequencies $f_1, \ldots f_k$

      (aa) generating a continuous vibrational wave at a surface of the layer;

      (ab) measuring an energy of a steady state echo wave produced in the object in response to the generated vibrational wave;

   (b) calculating the thickness of the layer based upon the measured energies of the steady state echo waves.

2. The method of Claim 1, further comprising a step of determining two or more frequencies $f_{n1}, f_{n2}, \ldots f_{nj}$ among the $f_1 \ldots f_k$ at which the energy of the steady state echo wave has a local minimum.

3. The method of Claim 2, wherein the thickness is calculated based upon f_{n1}, $f_{n2} \ldots f_{n3}$.

4. The method of Claim 3, wherein the number of frequencies at which the energy of the steady-state echo has a local minimum between f_{nl}, and f_{nl+1} is a constant m for all l between 1 and j-1.

5. The method according to Claim 4, wherein m is zero.

6. The method of Claim 4, wherein the thickness of the layer is calculated based upon the ratios $\frac{f_{n2}}{f_{n1}}, \frac{f_{n3}}{f_{n2}} \ldots \frac{f_{nj}}{f_{nj-1}}$.

7. The method of Claim 6, wherein calculation of the thickness involves solving the over determined system of equations for n_1

$$\frac{f_{n2}}{f_{n1}} = \frac{2(n_1 + m + 1) - 1}{2n_1 - 1}$$

$$\frac{f_{n3}}{f_{n2}} = \frac{2(n_1 + 2m + 1) - 1}{2(n_1 + m + 1) - 1}$$

.
.
.

$$\frac{f_{nj}}{f_{nj-1}} = \frac{2(n_1 + (j-1)m) - 1}{2(n_1 + (j-2)m + 1) - 1}$$

8. The method of Claim 7, wherein the thickness x_1 is calculated according to the algorithmic expression:

$$x_1 = \frac{(2n_1 - 1)c}{4f_{n1}},$$

where c is a speed of the waves in the layer.

9. The method of Claim 6, wherein calculation of the thickness involves solving the over determined system of equations for n_1

$$\frac{f_{n2}}{f_{n1}} = \frac{n_1 + m + 1}{n_1}$$

$$\frac{f_{n3}}{f_{n2}} = \frac{n_1 + 2m + 1}{n_1 + m + 1}$$

.
.
.

$$\frac{f_{nj}}{f_{nj-1}} = \frac{n_1 + (j-1)m + 1}{n_1 + (j-2)m + 1}$$

10. The method of Claim 9, wherein the thickness x_1 is calculated according to the algorithmic expression:

$$x_1 = \frac{n_1 c}{2f_{n1}},$$

where c is a speed of the waves in the layer.

11. A method for detecting the thickness of a bone, in an organism the method comprising the steps of:

(a) for each of a plurality of frequencies $f_1, \ldots f_k$

(aa) generating a continuous vibrational wave at a surface of the bone;

(ab) measuring an energy of a steady state echo wave produced in the organism in response to the generated vibrational wave;

(b) calculating the thickness of the bone based upon the measured energies of the steady state echo waves.

12. A device for determining a thickness of a layer in an object, the device comprising:

(a) a transducer configured to generate a plurality of input vibrational wave pulses;

(b) a receiver configured to receive a steady-state echo wave produced by an input vibrational wave pulse;

(c) a probe configured to transmit a vibrational wave from the transducer to a surface of the layer and to transmit steady-state echo wave from the surface to the receiver;

(d) a processor configured to

(da) determine a frequency of each of the plurality of input vibrational waves;

(db) store in a memory an energy of each of a plurality of steady- state echo waves; and

(dc) calculate the thickness based upon the stored energies of the steady-state echo waves; and

(e) a display configured to display the thickness.

13. The device according to Claim 12, wherein the probe has an acoustic impedance Z_{in} satisfying $Z_{in} > Z_i$, wherein Z_i is an acoustic impedance of the layer.

14. The device according to Claim 13, wherein Z_{in} further satisfies $Z_1 + \frac{Z_2 Z_{in}}{Z_1} \rangle Z_2 Z_{in}$, wherein Z_2 is the acoustic impedance of a region of the object juxtaposed to the layer.

15. The device according to Claim 13, wherein Z_{in} further satisfies $Z_2 + Z_{in} \rangle Z_1 + \frac{Z_2 Z_{in}}{Z_1}$, wherein Z_2 is the acoustic impedance of a region of the object juxtaposed to the layer.

16. A device for determining a thickness of a bone in an organism, the device comprising:

(a) a transducer configured to generate a plurality of input vibrational wave pulses;

(b) a receiver configured to receive a steady-state echo wave produced by an input vibrational wave pulse;

(c) a probe configured to transmit a vibrational wave from the transducer to a surface of the bone and to transmit steady-state echo wave from the surface to the receiver;

(d) a processor configured to

(da) determine a frequency of each of the plurality of input vibrational waves;

(db) store in a memory an energy of each of a plurality of steady-state echo waves; and

(dc) calculate the thickness based upon the stored energies of the steady-state echo waves; and

(e) a display configured to display the thickness.

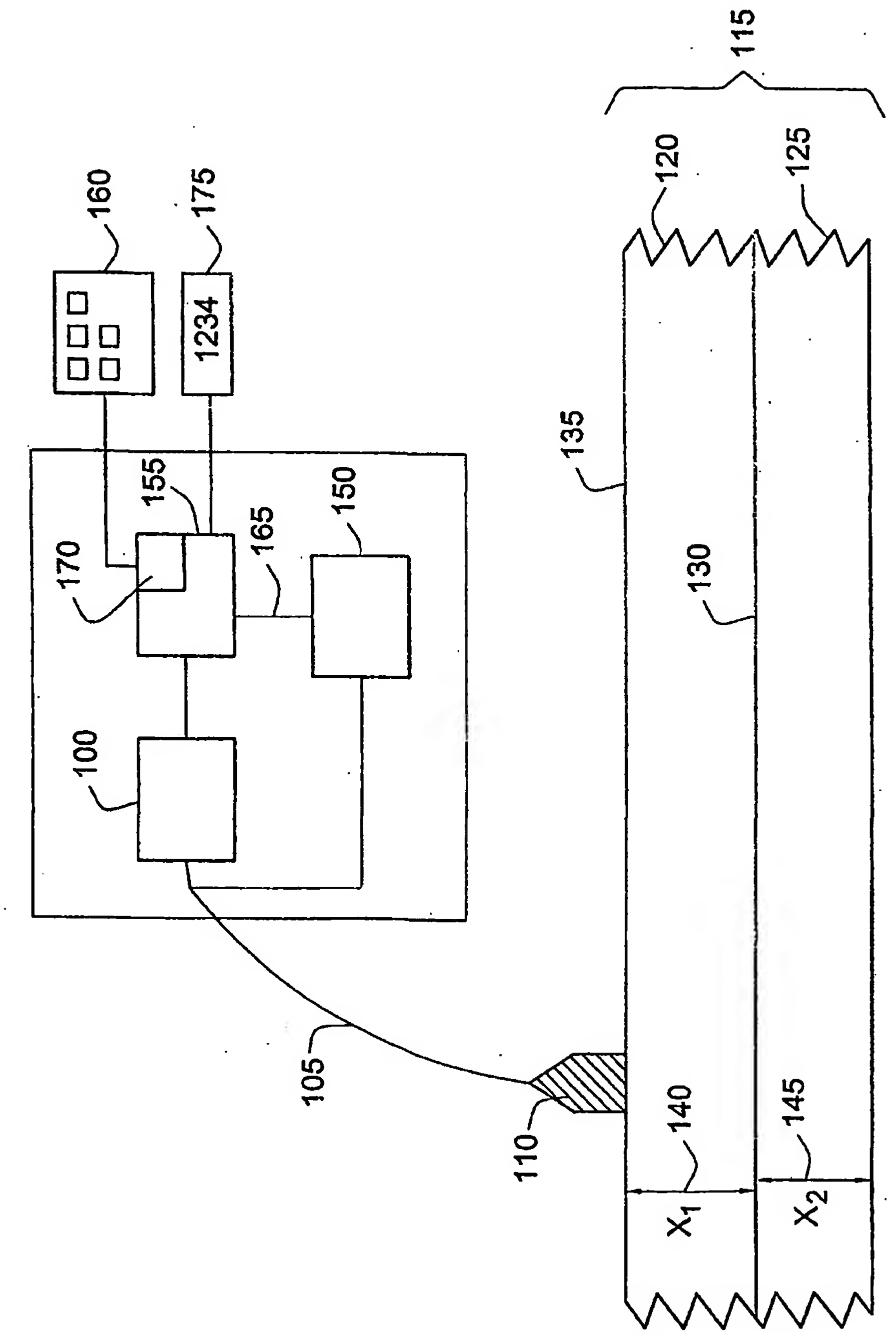
115
120
125
160
175
1234
135
155
165
150
170
130
100
105
110
140
145
X_1
X_2

FIG. 1

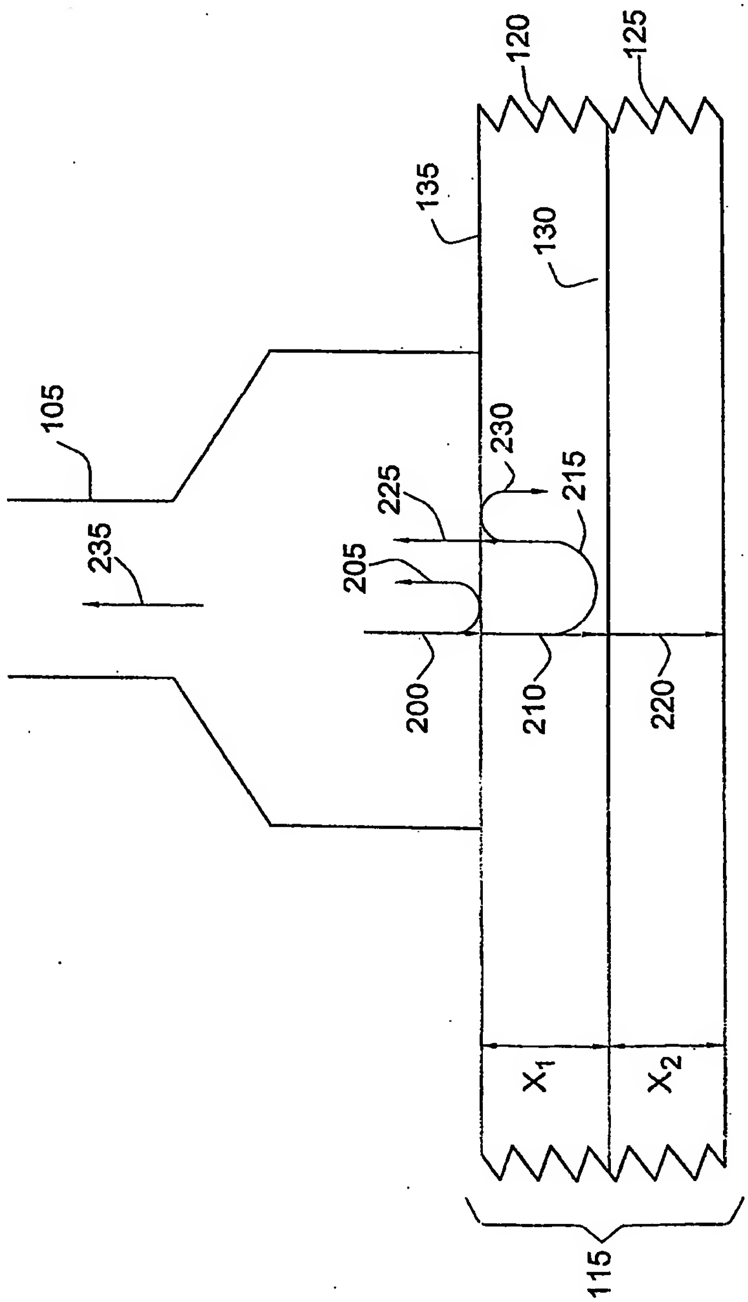

FIG. 2

INTERNATIONAL SEARCH REPORT

Interna Application No
PCT/IL 01/00794

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61B8/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61B G01B G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 34 25 811 A (FRAUNHOFER-GESELLSCHAFT) 14 March 1985 (1985-03-14) page 10, line 23 -page 11, line 20 page 14, line 17 -page 16, line 11 page 19, line 18 -page 21, line 7 figures 1-4	1,11,12, 16
X	US 5 908 388 A (WATKIN ET AL.) 1 June 1999 (1999-06-01) column 2, line 64 -column 3, line 33 column 3, line 54 -column 6, line 59 figures	12,16

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 February 2002	13/02/2002
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Chen, A

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 01/00794

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 351 544 A (ENDO ET. AL.) 4 October 1994 (1994-10-04) cited in the application column 6, line 42 -column 7, line 37 column 11, line 1 -column 16, line 12 figures 5-13 ---	12,16
A	US 5 197 019 A (DELON-MARTIN ET AL.) 23 March 1993 (1993-03-23) cited in the application column 3, line 55 -column 7, line 64 -----	1,11,12, 16

INTERNATIONAL SEARCH REPORT

Intern Application No
PCT/IL 01/00794

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
DE 3425811	A	14-03-1985	DE	3425811	A1	14-03-1985
US 5908388	A	01-06-1999	NONE			
US 5351544	A	04-10-1994	JP	4188058	A	06-07-1992
			DE	4138328	A1	27-05-1992
US 5197019	A	23-03-1993	FR	2650071	A1	25-01-1991
			CA	2021509	A1	21-01-1991
			DE	69000081	D1	04-06-1992
			EP	0409054	A1	23-01-1991
			JP	3057907	A	13-03-1991
			NO	903643	A	21-02-1991

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 31034 PC 01	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/DK 03/00587	International filing date *(day/month/year)* 11/09/2003	(Earliest) Priority Date *(day/month/year)* 11/09/2002
Applicant BETA LASERMIKE		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 4 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

[ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

[ ] contained in the international application in written form.
[ ] filed together with the international application in computer readable form.
[ ] furnished subsequently to this Authority in written form.
[ ] furnished subsequently to this Authority in computer readble form.
[ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
[ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

[X] the text is approved as submitted by the applicant.
[ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

[X] the text is approved as submitted by the applicant.
[ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 2

[ ] as suggested by the applicant.
[X] because the applicant failed to suggest a figure.
[ ] because this figure better characterizes the invention.
[ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/DK 03/00587

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01B17/02 G01B21/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01B B23B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 974 886 A (GILMORE ROBERT SNEE ET AL) 2 November 1999 (1999-11-02) column 2, line 1 -column 3, line 36 column 4, line 19 - line 36 column 5, line 11 - line 29 column 6, line 42 - line 62 column 7, line 64 -column 8, line 13 column 9, line 3 - line 52 figures 1-5 ---	1-10,12, 13,17-24
X	US 5 197 019 A (FARINE PIERRE-ANDRE ET AL) 23 March 1993 (1993-03-23) column 2, line 27 -column 4, line 36 --- -/--	1-12, 15-17, 19-24

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 December 2003	07.01.04

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	ENDER DAG/MN

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/DK 03/00587

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 957 337 A (EMERSON ELECTRIC CO) 17 November 1999 (1999-11-17) column 1, line 42 -column 5, line 47; figures 1-5	1,2,15, 19-21
X	WO 02 19914 A (SHIHADEH ELIAS EDMOND) 14 March 2002 (2002-03-14) column 5, line 3 -column 6, line 7; figure 2	1-5,21

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/DK 03/00587

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			CA	2021509	A1	21-01-1991
			DE	69000081	D1	04-06-1992
			EP	0409054	A1	23-01-1991
			JP	3057907	A	13-03-1991
			NO	903643	A	21-02-1991
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			JP	11325868	A	26-11-1999
			TW	412631	B	21-11-2000
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